RESEARCH DEPARTMENT

Local-oscillator interference with U.H.F. television reception

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LOCAL-OSCILLATOR INTERFERENCE WITH U.H.F. TELEVISION RECEPTION

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W. Proctor Wilson

J.G. Spencer

(W. Proctor Wilson)

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LOCAL-OSCILLATOR INTERFERENCE WITH U.H.F. TELEVISION RECEPTION

SUMMARY

This report discusses the possible effects of local-oscillator interference, from u.h.f. and v.h.f. receivers, with u.h.f. television reception. Measures which can be taken in respect of u.h.f. station planning and receiver design in order to minimize these effects are indicated.

1. INTRODUCTION

One factor which must be taken into account when planning a u.h.f. television transmitter network is the possibility of interference caused by radiation, at the local-oscillator frequency or its harmonics, from nearby receivers. Two receivers operating in adjacent semi-detached or terrace houses may be only a few feet apart. Their feeders may lie close together over part of their length, and terminate in aerials mounted on the same chimney-stack. Interference can thus be caused by radiation from a receiver, either directly from the chassis or viâ the aerial, and can be picked up by a neighbouring receiver, again either directly or viâ the aerial.

The radio industry has recently recommended limits to the permissible u.h.f. radiation at the fundamental oscillator frequency of a u.h.f. tuner, and at harmonics of the oscillator frequency of a v.h.f. tuner operating in Band III. The main object of the present report is to assess the effect of such radiation from receivers complying with these recommendations.

2. INTERFERENCE FROM OTHER RECEIVERS OPERATING ON U.H.F.

The fundamental local-oscillator frequency of a television receiver with the standard 39·5 Mc/s i.f., tuned on u.h.f., say, to Channel N, will fall 500 kc/s below the vision carrier frequency of Channel N+5 and 7·5 Mc/s above the vision carrier frequency of Channel N+4. Present planning standards avoid the use of 5-channel separation between transmitters which are co-sited or in adjoining areas but, with the frequency allocations so far agreed, the great majority of co-sited transmitter groups have one pair of channels with N to N+4 relationship. We must therefore consider the possibility of interference occurring in this case, bearing in mind the possibility that the interfering receiver may be considerably mistuned.

As a result of discussions between the radio industry and the General Post Office, the British Radio Equipment Manufacturers' Association (BREMA) has recently issued a recommendation on the permissible upper limit of radiation in the u.h.f. band from local oscillators of television receivers.[2] As far as receivers operating at u.h.f. are concerned, the maximum permissible field strength of radiation at the oscillator fundamental frequency is specified as 3 mV/m at a distance of 3 m, measured in accordance with the method prescribed in I.E.C. Publications 106 and 106A, with a 30 cm dipole (a half-wavelength at 500 Mc/s) connected to the receiver. In order to assess the interference which may result we require to know the degree of coupling between receiving installations in adjacent houses and the possible mistuning of a u.h.f. television receiver.

2.1. Coupling between Adjacent Receiver Installations

In view of the totally screened form of construction adopted in current designs of u.h.f. tuner and the wide use of screened coaxial feeders, it will be assumed that the major component of coupling between receiving installations in adjacent houses is that between the aerials. Laboratory experiments have been carried out (see Appendix) with arrangements simulating the type of installation frequently encountered in semi-detached houses, where the two aerials are mounted on a common chimney-stack. An average value for the coupling, in terms of the ratio of the voltage developed at the input of the 'interfered with' receiver to that applied to the feeder of the interfering receiver, is −50 dB.

If we now consider an interfering receiver which just complies with the BREMA recommendation, and which produces the specified 3 mV/m at 3 m entirely by radiation from the test dipole connected to its aerial terminals, the interference voltage at these aerial terminals will be 81 dB(μV).* Strictly speaking, this is only correct at the frequency at which the dipole is a half-wavelength and if the effects of ground reflexions in the standard test are ignored. It is, however, sufficiently accurate for the present purpose.

With such a receiver as the source of interference, the interference voltage at the input to the adjacent receiver will be 31 dB(μV).

2.2. Mistuning of the Interfering Receiver

Laboratory tests were carried out on twelve monochrome u.h.f. television receivers of British manufacture to determine the maximum tuning error consistent with acceptable picture and sound reception.[3] Of this number, one receiver could be mistuned by −3 Mc/s, two by −2·5 Mc/s and a further three by −2 Mc/s. The negative sign here indicates that the receiver was tuned to a frequency lower than that of the channel being received, i.e. the local-oscillator frequency was shifted downwards. It therefore is reasonable to assume that mistuning of −2·5 Mc/s may be encountered with u.h.f. receivers in the hands of the general public.

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* Measurements of the local-oscillator voltage at the aerial terminal of a receiver are usually made and quoted in terms of the p.d. across a terminating resistance equal to the nominal input resistance of the receiver. Throughout this report, for convenience in calculating, all r.f. voltages, both signal and interference, are given in terms of the p.d. across a load of 75Ω.

This assumption applies only to monochrome reception. With a colour receiver, operating on a colour transmission, such severe mistuning is unlikely to occur, since it would produce unacceptable degradation of the colour picture. However, the total number of colour receivers in use is likely to be small for some years to come, and will not affect the incidence of interference significantly.

2.3. Assessment of Interference with Monochrome Reception of a Monochrome Transmission

Fig. 1 gives the required protection ratio against a c.w. signal for monochrome and NTSC colour television systems, based on the technical data used by the European V.H.F./U.H.F. Broadcasting Conference, Stockholm 1961.* The curves of Fig. 1 correspond to 'just perceptible' interference and have been derived from curves giving the level of interference acceptable for a small percentage of the time by increasing the stated protection ratios by 15 dB.

Mistuning of the interfering receiver on Channel N by -2·5 Mc/s will give rise to interference which lies 5 Mc/s above the vision carrier of Channel N+4. From Fig. 1, the protection ratio required in this case is 30 dB for a monochrome

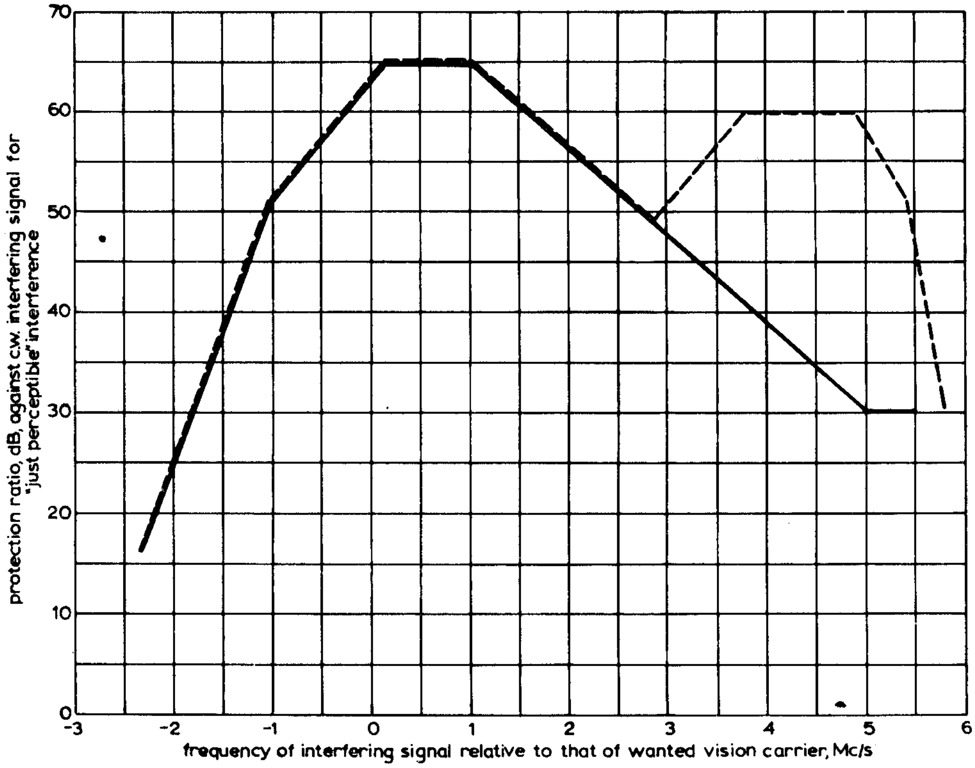

Fig. 1 – Protection ratio required against c.w. interference

——— Monochrome system
- - - - Adapted NTSC colour system

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* With the SECAM colour system this type of interference is not greatly different on the average, although there is some evidence[4] that it may be more serious for certain frequency differences. The PAL system appears from preliminary tests to be closely similar to NTSC. Since no protection ratio curve is available for the other systems this report is based throughout on the NTSC figures.

system. From Section 2.1, a receiver complying with the BREMA recommendation could give an interfering signal of 31 dB(μV); the wanted signal input voltage for just perceptible interference is therefore 61 dB(μV). Assuming that the aerial of the 'N+4' receiver has a gain of 10 dB relative to a λ/2 dipole and a feeder loss of 4 dB, and that the wanted signal frequency is 650 Mc/s, the corresponding field strength required to reduce the subjective rating of the interference to 'just perceptible' is 78 dB(μV/m). This must be compared with the nominal field strength of 70 dB(μV/m) at the limit of the service area.

The curve in Fig. 1 presupposes that the receiver suffering interference has the full bandwidth ideally required for the system, and is accurately tuned. Any restriction of bandwidth, or mistuning the receiver to reduce the response to the higher modulation frequencies, would reduce the severity of interference of this type. (Mistuning in the opposite sense – shifting the vision carrier down the vestigial slope – is unlikely to occur in view of the rapid degradation of picture which results).

If we consider only monochrome television, it therefore appears that 'N to N+4' type interference may be experienced by viewers in fringe areas using receivers with full bandwidth, if the interfering receiver is mistuned. Its effect can be ameliorated, at the expense of a loss of picture sharpness, by detuning the viewer's receiver and could probably be eliminated completely by shifting the position of the u.h.f. aerial. The latter remedy would usually mean calling in the local radio dealer and would hence entail some expense to the viewer.

2.4. Assessment of Interference with Colour Reception of a Colour Transmission

From Fig. 1, the protection ratio required against a c.w. signal offset by 5 Mc/s from the vision carrier is 58 dB for a colour system. With the assumptions made in Section 2.3, this demands a wanted signal field strength of 106 dB(μV/m). Colour receivers are more likely to have the full bandwidth required by the system and cannot be detuned to any great extent without serious degradation of the colour picture.

The only expedient open to the 'colour viewer' to reduce the severity of interference arising from this source would be moving his u.h.f. aerial. Even if the aerial coupling were reduced to –70 dB, and assuming that at this level direct coupling between the receivers could still be ignored, the protected field strength would then be 86 dB(μV/m), i.e. 16 dB in excess of the nominal field at the fringe of the service area.

2.5. Compatible and Reverse-Compatible Reception

In addition to completely monochrome or completely colour transmission and reception there is also the important case of compatible reception, i.e. the reception of a colour transmission on a monochrome receiver. In this case an interfering c.w. signal which is offset by more than about 2·5 Mc/s above the vision carrier frequency will cause more disturbance than would be the case if the transmission were in monochrome. This is due to the presence of a low-frequency component in the beat pattern corresponding to the frequency difference between the interfering signal and the colour sub-carrier. Laboratory tests on a 405-line NTSC colour system[3] have shown that the susceptibility of a colour transmission to c.w. interference is sensibly the same with compatible monochrome reception as it is with colour reception, and there appears to be no reason why this should not apply equally to a 625-line system. Departures of the receiver response from the ideal may, however, ease the position slightly as compared with that for colour reception.

With reverse compatible reception, i.e. the use of a colour receiver on a monochrome transmission, tests with a 405-line system[5] showed that, for interfering signals about the 'just perceptible' level, results were very similar to those applying to a monochrome receiver. As the amplitude of an interfering signal in the region of the colour sub-carrier frequency was increased, however, a threshold was reached at which the 'colour killer' ceased to operate, and the interference pattern appeared in the form of coloured stripes with a resulting sharp increase in visibility. Such difficulties may be reduced by improved receiver design, but they should not be overlooked. It may be necessary to fit a manually operated 'colour killer' in addition to any automatic one as a safeguard against such avoidable effects of interference; with this reservation, reverse compatible reception can be regarded as requiring the same protection as normal monochrome transmission and reception.

With both compatible and reverse compatible reception, as in the monochrome case, the viewer can reduce the effect of 'N to N+4' interference, at the expense of some loss of picture sharpness, by slight detuning of his receiver.

3. INTERFERENCE FROM BAND III RECEIVERS

Interference to u.h.f. reception can also be caused by harmonics of the local-oscillator frequency of receivers operating in Band III and, in the current u.h.f. plan,* eleven areas have one channel which is vulnerable to this form of interference. The beat frequency which can be produced with the u.h.f. channel allocations adopted for the U.K. at Stockholm in 1961[6], varies over the video range; it may be as low as 50 kc/s (as in the case of receiving a signal from the Lanarkshire u.h.f. transmitter on Channel 50 in the proximity of a receiver tuned to Black Hill on Channel 10.)

The BREMA recommendation[2] for the permissible upper limit of radiation in the u.h.f. band from receivers operating in Band III is 600 μV/m at 3 m. With receivers of this type, experiments have shown that the levels of radiation from the chassis and from the aerial can be comparable.[7] In assessing the probable effects of interference we will therefore assume two alternative possibilities, viz., that the radiation is either wholly from the aerial or wholly from the chassis. As an illustration, we may take the case of the Birmingham u.h.f. transmitter on Channel 46, which is subject to interference from the third harmonic of the local oscillator of a receiver tuned to Lichfield on Channel 8. The beat frequency here is 1·95 Mc/s and, from Fig. 1, the protection ratio required is 56 dB.

Consider first the case of a receiver, just complying with the BREMA recommentation, which radiates interference only by virtue of the oscillator harmonic voltage appearing at its aerial terminal. On the same simplifying assumptions as were made in Section 2.1 for the u.h.f. receiver case, this voltage will be 67 dB(μV). An average value for the coupling between a Band III and a u.h.f. aerial with 2·7 m separation is 50 dB (see Appendix); thus the interference voltage at the input to the u.h.f. receiver will be 17 dB(μV). To give a protection ratio of 56 dB, therefore, a wanted signal of 73 dB(μV) i.e. a field strength of 90 dB(μV/m) is required.

If the interference is assumed to be radiated entirely from the Band III receiver chassis, the effect will depend on the susceptibility of the neighbouring u.h.f. receiver to direct pick-up. Measurements of this aspect of performance have been made by the GPO Engineering Department.[8] Seven receivers were tested and, in terms of the ratio of the field strength at the receiver to that at the aerial for a given effective input signal to the receiver, the measured figures ranged from 18 dB to 32 dB.* The conditions of the test were such that the performance of the better receivers tended to be masked by other sources of signal pick-up, so that in fact the upper limit of the range could be considerably higher than 32 dB. The worst two ratios measured, 18 dB and 24 dB, probably represent the true performance of the receivers in question and, for the purpose of this assessment it will be assumed that a significant proportion of the u.h.f. receivers in use will have a ratio of direct pick-up to aerial pick-up of -26 dB. In very many domestic installations the television receivers in adjacent houses are disposed on either side of a party wall only five or six feet apart. Allowing for the attenuation due to the wall, the interference field strength in the vicinity of the u.h.f. receiver will be taken as 56 dB(μV/m). A protection ratio of 56 dB will thus require a wanted signal field strength of 56 - 26 + 56 dB = 86 dB(μV/m).

Viewers in situations where the u.h.f. field strength is inadequate to give protection against such Band III harmonic interference could do little to reduce its effects. Where the interference frequency is well within the receiver bandwidth, detuning will confer little benefit. Changing the position of the u.h.f. aerial will also be of no use if direct coupling between receivers alone is sufficient to produce a troublesome level of interference. Changing the position of the receiver itself will, of course be effective in the latter case, but the viewer may be reluctant to move the receiver from its accustomed niche beside the fireplace.

Interference from Band III receivers would therefore be expected, in the service area of the Birmingham transmitter on Channel 46, where the field strength is less than 86 - 90 dB(μV/m), and it might be difficult to suggest any means acceptable to the affected viewer for alleviating it. The case calculated does not represent the worst instance of this form of interference. The transmission on Channel 50 in Lanarkshire, for example, which serves an area which is quite densely populated, is subject to interference from the third harmonic of the local oscillator of a receiver tuned to the local Band III transmitter at Black Hill. In this case the frequency offset is -50 kc/s and the protection ratio required is 63 dB, 7 dB greater than that in the previous example. Here, the field strength required to give protection would be above 90 dB(μV/m).

4. DISCUSSION

The BREMA recommendation[2] recognizes that, even if receivers do conform with the proposed specifications, oscillator radiation may still present a significant problem and manufacturers are urged to keep the radiation level of their receivers as low as possible. Assuming, however, that the figures given represent the limit of what is practicable in production in the present state of the art, there are other aspects of receiver performance which will affect the severity of this form of interference.

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* These figures are based on the sensitivity of a 12-element u.h.f. Yagi aerial to signals arriving from the direction in which the gain is greatest, and the ratios derived are hence usable directly in the later calculation. The standard form of test for direct pick-up (as in B.S. 905) is based on the use of a half-wavelength dipole aerial and the results then obtained would not be directly applicable.

If u.h.f. receivers were so designed that the tuning error could not exceed, say, 1 Mc/s, N to N+4 interference would present no problem with either monochrome or colour transmissions. Tuning indicators would help in this regard, but they can be ignored by the user; a.f.c., of the type which is automatically switched out while the receiver is being tuned, is a better solution but may be prohibitively expensive for the cheaper receivers. One approach which might be possible would be to ensure that the i.f. amplifier response below 33·5 Mc/s falls sufficiently rapidly to ensure that the sound signal becomes unusable with gross mistuning.

The susceptibility of u.h.f. receivers to direct interference pick-up is another factor which affects the problem. Interference due to aerial and feeder coupling can be reduced by careful siting of the aerial system (although the cost and inconvenience which this may cause to the viewer should not be ignored). Interference caused by direct coupling between receivers, however, may be more difficult to deal with, since the location of a domestic television receiver is decided by other than technical considerations, and may well set an irreducible minimum to the level of interference experienced at any given site. It is, therefore, highly desirable that some limit, similar to that prescribed in B.S. 905 : 1959, Clause 14, for v.h.f. receivers, be recommended for the susceptibility of u.h.f. receivers to radiated interference. It would assist in the formulation of this limit if the measurement of local-oscillator radiation were made more informative. The current method of testing measures the radiated field at a distance of 3 m from the receiver when connected to a dipole aerial. A form of test could be devised in which separate measurements are made of the level of direct radiation from the chassis and of the interference voltage appearing at the aerial terminal of the radiating receiver. From such measurements, it would be possible to estimate the level of interference field strength likely to exist in the vicinity of a neighbouring u.h.f. receiver and hence to define the limit of susceptibility to direct pick-up which could be tolerated.

5. CONCLUSIONS

Interference with u.h.f. reception can be caused by television receivers operating either in the u.h.f. band or in Band III.

With the upper limit proposed by BREMA of 3 mV/m on local-oscillator radiation from television receivers operating on u.h.f., 'N to N+4' interference may be caused to monochrome transmissions in fringe areas. This is not, however, expected to be serious, and where it does occur it could, in most cases, be eliminated by altering the position of the u.h.f. aerial.

Colour reception of a colour transmission requires 20 to 30 dB more protection against this form of interference; monochrome reception of a colour transmission requires less protection than this but still substantially more than with monochrome transmission and reception. If in general the radiation level from u.h.f. receivers approaches the proposed limit it will therefore be virtually impossible to use, for colour transmission, any channel which is in N+4 to N relationship with another channel receivable in the same area.

The foregoing conclusions pre-suppose that u.h.f. receivers use the standard intermediate frequency of 39·5 Mc/s. If, either by design or through inaccurate alignment, receivers operating on an appreciably lower intermediate frequency were produced, the N to N+4 interference problem would be more serious. If, on the other hand, u.h.f. receivers could be so designed that the possible tuning error could not exceed about 1 Mc/s, this form of interference would be reduced to negligible proportions with both monochrome and colour transmissions.

The u.h.f. channel allocations in all but eleven areas in the U.K. are such that no interference will occur from local-oscillator harmonics radiated by receivers operating on Band III. In these eleven areas, however, Band III receivers whose local-oscillator radiation just conforms to the BREMA recommended limit of 600 μV/m will cause interference, the severity of which will depend on the frequency of the resulting beat pattern. In the worst cases, where the beat pattern corresponds to a low frequency, the field strength required to give protection against this form of interference will be above 90 dB(μV/m), i.e. more than 20 dB above the field strength in the fringe of the service area.

These calculations are based on a number of assumptions. A more accurate assessment of the magnitude of the problem could be made if more information were available, first, about the susceptibility of u.h.f. receivers to direct pick-up of radiated interference and, second, about the respective contributions to the total interference field of direct radiation from the receiver chassis and of the interfering voltage applied to the aerial.

BREMA recognizes that the permissible limits of oscillator radiation which it recommends will result in an appreciable amount of interference, and urges manufacturers to achieve as low a level of radiation as is practicable. We strongly endorse this view. We also suggest that, if the results of the tests referred to in the preceding paragraph show that direct coupling between receivers is likely to be a significant source of interference, some agreed limit be recommended for the susceptibility to radiated interference of u.h.f. receivers, in addition to the necessary limit on the level of local-oscillator radiation.

6. ACKNOWLEDGEMENTS

The author is indebted to Mr. D.J. Whythe for the information on coupling between aerials presented in the Appendix. Discussions with other colleagues in the BBC Research Department have also been most helpful, and the assistance thereby obtained is gratefully acknowledged.

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8. APPENDIX: COUPLING BETWEEN NEIGHBOURING TELEVISION AERIALS AT U.H.F.

Typical receiving aerials were erected about 10 m above flat ground and arranged to represent electrically the installations that might be used in adjacent houses, including cases expected to be the worst for mutual interference. The insertion losses between the aerials were measured at u.h.f. to provide information in estimating the importance of local-oscillator radiation effects.

The aerials employed were two wide-band u.h.f. aerials covering Bands IV and V (Füba, type DFA 1 LM 13, a 13-element Yagi) and a typical Band III aerial (Antiference, type 354, a 5-element Yagi). For each aerial a 75-ohm flexible coaxial down-lead of a type used in domestic installations was used, the total length of each feeder being about 20 m. When measuring the coupling, the two feeders of the aerials concerned were kept about 2·5 m apart. With each feeder terminated at the upper end in a matching resistor, the measured insertion loss between the lower ends was over 80 dB in the frequency range 500 to 800 Mc/s.

Tables 1 and 2 summarize the measured insertion losses at u.h.f. for different arrangements of (a) two u.h.f. aerials and (b) a u.h.f. aerial and a Band III aerial. Arrangement (b) is important because harmonics of the local oscillator of a Band III tuner can also cause interference. In all cases the aerials were set as if directed towards a single transmitting site. The values of insertion loss are corrected to correspond to the case in which the attenuation in each feeder is 4 dB at u.h.f. For spacings greater than 2·7 m the attenuation falls by 6 dB if the spacing is doubled. The insertion loss between two u.h.f. aerials was found to be greatest when, with horizontal separation, the line joining the aerials was at 90° to the direction of maximum pick-up; with 2·7 m separation the insertion loss was very large - of the same order as that between the feeders alone.

TABLE 1

Insertion loss between two u.h.f. aerials

SEPARATION	LINE OF SEPARATION RELATIVE TO DIRECTION OF MAXIMUM PICK-UP	INSERTION LOSS AT 650 Mc/s*, dB
2·7 m horizontally	0°	46
2·7 m horizontally	45°	52
0·9 m vertically	90°	33 (31)
0·9 m horizontally	90°	54 (46)

TABLE 2

Insertion loss between u.h.f. aerial and Band III aerial

		INSERTION LOSS AT 650 Mc/s*, dB	
SEPARATION	LINE OF SEPARATION RELATIVE TO DIRECTION OF MAXIMUM PICK-UP	Band III elements vertical	Band III elements horizontal
1·2 m vertically	90°	48 (48)	60 (38)
2·7 m horizontally	0° (A)	45 (39)	48 (34)
" "	0° (B)	62 (58)	58 (54)
" "	45° (B)	64 (51)	64 (51)
" "	90°	62 (50)	51 (45)

* Figures in brackets are the lowest values found in the frequency range 500 to 750 Mc/s with measurements at 50 Mc/s intervals.

(A) Band III aerial situated in forward direction of u.h.f. aerial
(B) Band III aerial situated in backward direction of u.h.f. aerial

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